Eskom
Power factor: Technical overview
Fact Sheet

Eskom

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Reducing electricity costs with improved power factor

A facility's power factor will rarely be at 100% (unity) if mainly inductive loads with uncorrected power factor are operated. Poor power factor adds to the facility inefficiencies, increases operating costs, increases plant breakdowns, and subsequently increases maintenance costs. Eskom charges an additional reactive power (kVAR) fee where a facility's power factor is less than 0.96[1]. Low power factor also reduces the electrical system's distribution capacity by increasing current flow, thereby reducing the distribution network voltage.

Improving a poor power factor is not difficult and often a guaranteed way of saving on additional electricity supply capacity costs and the existing electricity bill. The aim of this fact sheet is to provide technical information on power factor and how to improve it. Also refer to the power factor: Basic overview and power factor: Sizing brochures.

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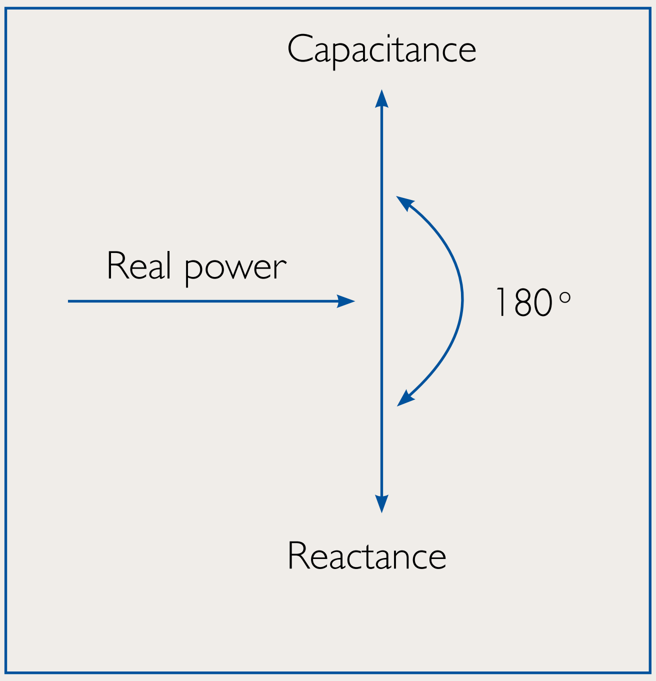
Correcting your power factor

A number of strategies exist for correcting your power factor. These are often combinations of various basic approaches, which may include:

- Minimising operation of idling or lightly loaded motors.
- Replacing standard motors when possible with energy-efficient motors. Even with energy-efficient motors, however, the power factor is significantly affected by variations in load. A motor must be operated near its rated capacity to realise the benefits of a high power factor design.
- Using shunt capacitors, kVAR panels or automatic power factor control (APFC) panels.
- Installing capacitors in your AC circuit to decrease the magnitude of reactive power (this is the most widely used method).

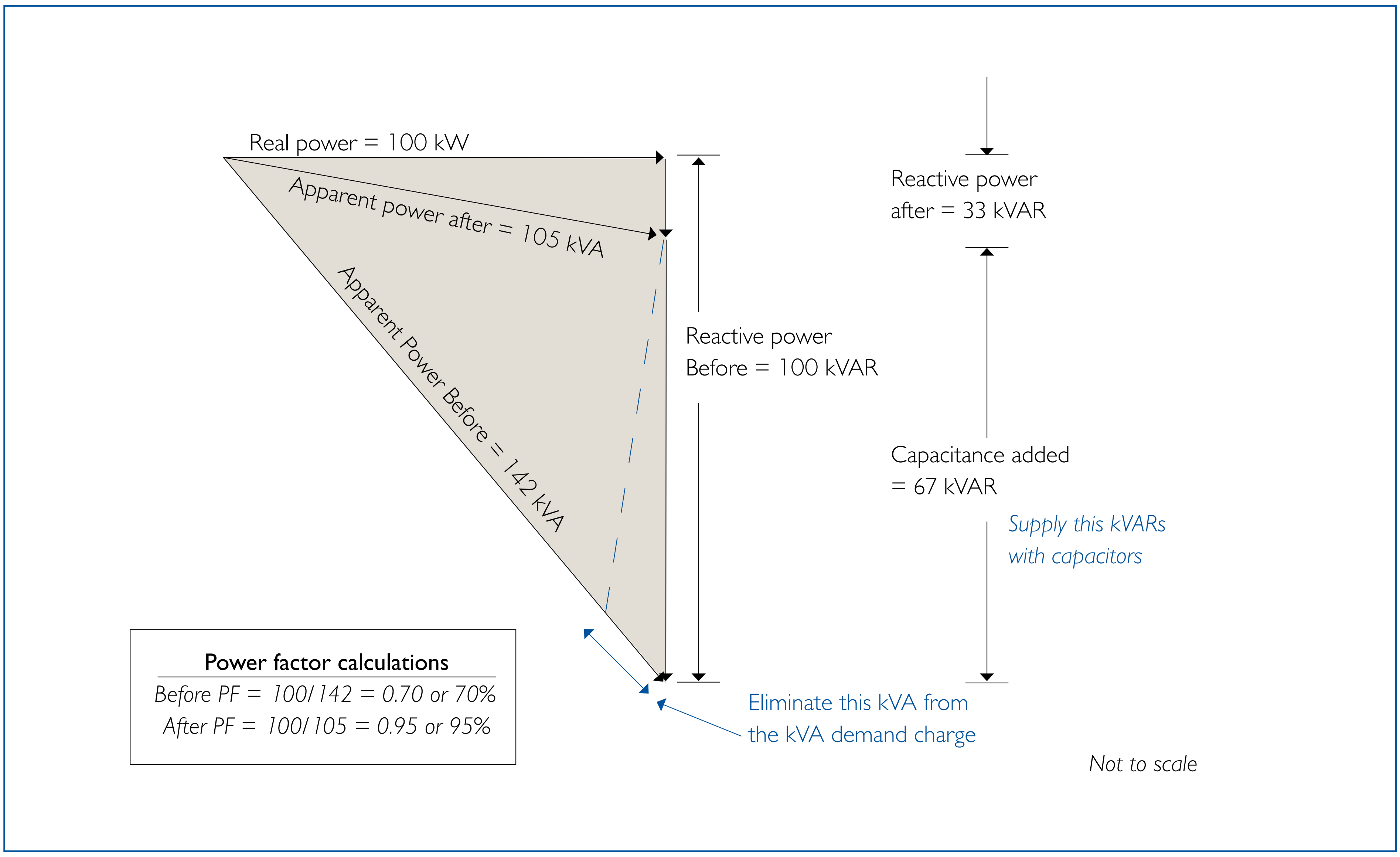
As shown in the diagram below, reactive power (measured in kVARs) caused by inductance always acts at a 90° angle to real power. Capacitors store kVARs and release energy opposing the reactive energy caused by the inductor. This implies that inductance and capacitance react 180° to each other.



The average cost of power factor improvement is usually 85% cheaper than an electrical supply upgrade!

The presence of both inductance and capacitance in the same circuit results in the continuous alternating transfer of energy between the capacitor and the inductor, thereby reducing the current flow from the generator to the circuit. When the circuit is balanced, all the energy released by the inductor is absorbed by the capacitor thereby reducing energy losses from the supply.

In the diagram below, the power triangle shows an initial 0.70 power factor for a 100kW (real power) inductive load. The reactive power required by the load is 100 kW. By installing a 67 kW capacitor, the apparent power is reduced from 142 to 105 kVA, resulting in a 26% reduction in current. Power factor is improved to 0.95.



In the "horse and railcart" analogy (from the power factor: Basic overview brochure), is equivalent to decreasing the angle the horse is pulling on the railcart by leading the horse closer to the center of the railroad track. Because the side pull is minimised, less total effort is required from the horse to do the same amount of work.

Capacitor suppliers and engineering firms can assist you to determine the optimum power correction factor and to correctly position and install capacitors in your electrical distribution system.

Typical power factor by industry type without correction

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Typical uncorrected industrial power factor should usually be approximately 0.8 (80%). This means that a 1 MVA transformer can only supply 800kW or that a consumer can only draw 80 useful Amps from a 100 Amp supply. Stated differently, a 3-phase 100kW load would draw 172A per phase instead of the 139A expected. For inherently low power factor equipment, the utility has to generate much more current than is theoretically required for an ideal plant. This excess current flows through generators, cables, and transformers in the same manner as the useful current increasing losses and reducing the lifespan of equipment. If steps are not taken to improve the power factor of the load, all the equipment from the power station to the installation sub-circuit wiring has to be larger than necessary to supply the load without detrimental impacts. This results in increased capital expenditure and higher transmission and distribution losses throughout the whole network.

Typical unimproved power factors by industry type are:

Industry	P.F. (%)	Industry	P.F. (%)
Auto parts	75-80	Machine manufacturing	60-65
Brewery	75-80	Metalworking	65-70
Cement	80-85	Office building	80-90
Chemical	65-75	Water pumping	40-70
Coal mine	65-80	Paint manufacturing	65-70
Clothing	35-60	Plastic	75-80
Electroplating	65-70	Metal pressing (Stamping)	60-70
Foundry	75-80	Steel works	65-80
Forging	70-80	Tool, dies, jigs industry	65-75
Hospital	75-80	Data centres	65-75

Typical benefits of power factor correction

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Benefit 1 - Reduce utility power bills

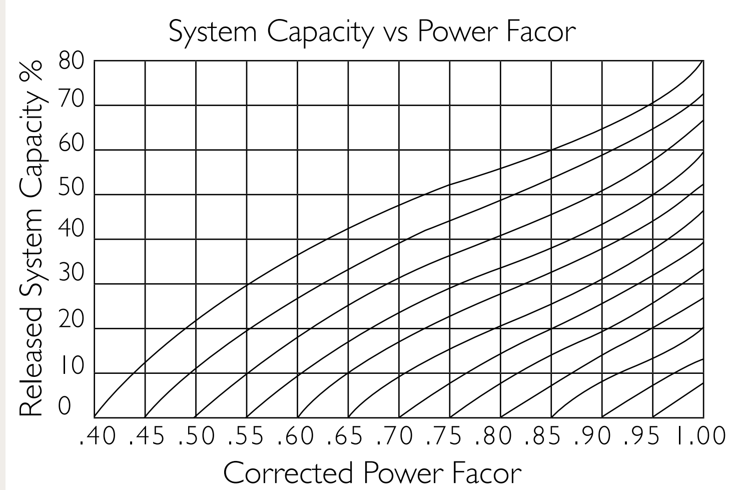
In areas where a kVA demand clause or some other form of low power factor penalty is incorporated in the electric utility's power tariff structure, removing system kVAR improves the power factor, reducing power bills by minimising the kVA. Most utility bills are influenced by kVAR usage.

Benefit 2 – Increase system capacity

The power factor improvement releases system capacity and permits additional loads (motors and lighting) to be added without overloading the system or paying for a network upgrade. In a typical system with a 0.80 PF, only 800 kW of productive power is available out of 1 000 KVA installed. By correcting the system to unity (1.0 PF), the kW = kVA. Then the corrected system will support 1 000 kW, versus the 800 kW at the 0.80 PF uncorrected condition; an increase of 200 kW of productive power.

This is achieved by adding capacitors which furnish the necessary magnetising current for induction motors and transformers. Capacitors reduce the current drawn from the power supply; less current means lower loading on transformers and feeder circuits. Power factor correction through devices such as capacitors can avoid an investment in more expensive transformers, switchgear and cable, otherwise required to serve additional load. The figure below shows the relationship between system capacity vs. power factor. From the figure, one finds that improving power factor from 0.8 to 0.9 or 0.8 to 0.95 will release approximately 12% or 20% system capacity respectively.

Benefit 3 - Improve system operating characteristics (gain voltage)



A good power factor (0.95) provides a "stiffer" voltage; typically a 1-2% voltage rise can be expected when power factor is brought to ± 0.95. Excessive voltage drops can make your motors sluggish, and cause them to overheat

Low voltages also interfere with lighting, the proper application of motor controls and electrical and electronic instruments. By improving the voltage regulation, motor performance is improved, control stability is improved reducing nuisance trips which improves productivity.

Benefit 4 - Improve system operating characteristics (reduce line losses)

Improving power factor at the load points will relieve the system of transmitting reactive current. Lower currents mean lower losses in the distribution system within the facility since losses are proportional to the square of the current (I2R). Therefore, fewer kilowatt-hours need to be purchased from the utility.

An estimate of the reduction of power losses can be made using the following equation:

% Reduction of Power Losses

$$= 100 - 100 \left(\frac{\textit{Original power factor}}{\textit{Improved power factor}} \right)^2$$

Typical power factor by equipment type without correction

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The power factor of commonly used electrical equipment provide an idea as to the amount of reactive energy that the network will have to carry. To the right is a summary of the power factor of common electrical equipment within industrial facilities.

Industry	P.F. (%)
Air compressor & pumps (external Motors)	75-80
Arc welding	35-60
Machining	40-65
Induction furnaces	100
High-speed metal pressing (stamping)	45-60
incandescent lamps	100
Mercury vapor lamps (without correction devices)	40-60
Induction motors (load dependent) – see next section	30-90
Industrial heating (resistance ovens & dryers)	~100

Industry	P.F. (%)
Hermetic motors (compressors)	50-80
Resistance welding	40-60
Arc furnaces	75-90
Standard metal pressing (stamping)	60-70
Spraying	60-65
Fluorescent lamps (without compensation device)	40-60
Distribution transformer (load & design dependent)	30-45 (no-load)
Synchronous motors: - With excitation properly adjusted: - With excitation over adjusted: - 100 - Can be used to compensate for low P.F.	
Conveyor systems	50-70

The causes of poor power factor

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The above list shows that a poor power factor can be a result of the design of the equipment, as in the case of welders, or it can result due to the operating conditions under which the equipment is used, as in lightly loaded induction motors, probably the worst offenders.

Equipment design

In an old installation, one is limited by the inefficiency of the existing system. However, given the opportunity to expand and purchase new equipment, consideration should be given to efficient electric equipment.

Operating conditions

The loading of equipment has a severe impact on some equipment, for example, the power factor of an electrical motor reaches its maximum value under full load. The power factor decreases rapidly when the load decreases. This Can be used to compensate for low P.F. symbolically illustrates the effect of the load on the power factor of a motor.

Motor Load Factor	P.F. (%)
Unloaded	17
½ (50%) Loaded	73
Fully (100%) Loaded	84

Industry	P.F. (%)
¼ (25%) Loaded	55
¾ (75%) Loaded	80
Overloaded (+25%)	86

Line voltage

Increasing the line voltage on motors and transformers above the rated voltage will increase the consumption of reactive energy.

The result will be a reduction in power factor. For example, an increase of 10% on the rated voltage can result in a 20% reduction of the power factor.

Power factor correction methods

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Older power factor correction systems were slow in correcting a poor power factor and resulted in limited to no benefits. Newer fast-response systems have the ability to correct poor power factor before the negative impacts are registered and billed.

Power factor correction can be installed in three ways:

1. **Individual capacitor installation at the level of each machine**

Capacitors for correcting power factor may be installed on the high voltage and/or the low voltage side of an electrical network.

Combining the required amount of capacitors at the main busbar will eliminate the power factor penalty but will not reduce the losses in the facility. Capacitors placed at this location are the most susceptible to harmonic resonance.

Distributing the capacitors to the motor control centres and subpanels proportional to average load will generally improve losses, although it is not an optimal solution.

Distributing the capacitors (using the motor sizes and the table provided under the heading "Determining Capacitor Requirements" as a guide) is a solution that does not meet the need for more released capacity if this is a goal. Capacitors sized for small loads are often proportionally much more expensive than larger fixed capacitors, primarily because of installation costs.

2. Group or bank installation

Switching a few of the capacitors with larger motors is an option. The capacitors may be physically installed either directly connected to the motor or through a contactor on the motor control centre that is tied in with the motor control. If the motors are large enough to use capacitors of the same size as were being considered for the fixed capacitor scheme, little additional cost is incurred for installing them on the motors. Where the economy is lost is when the capacitors are placed on several small motors. There is relatively little difference in installation costs for large and small 500-V units.

The second switching option is to consider an automatic power factor controller installed in the capacitor bank. This will switch large capacitor banks in small steps (25 through 50 is common) to follow the load. Automatic power factor capacitor banks should be installed at the motor control centre rather than on the main bus, if optimal distribution loss is a goal. The economics of purchasing, installing, protecting, and controlling single large automatically switched capacitor banks can sway the decision toward a main bus location, especially if the primary goal is to avoid power factor penalties.

Reactors can be added to fixed or automatic power factor capacitor banks to prevent the risk of the harmful effects of harmonics (detuned filters).

Mixed installation, at both the individual and group level

Installations not operating continuously and which may be supplied at high voltage but with low voltage loads should employ low voltage capacitors for power factor improvement. Low voltage switchgear is much cheaper than high voltage switchgear and is obviously available with much lower ratings which enable relatively small capacitor steps (100kVAR and below) to be employed for automatically controlled capacitors. This ensures flexibility of operation without excessive switchgear costs. The advantages and drawbacks of this option will be the same as under the first option.

Various types of power factor correction installation methods (static capacitor banks, dynamic banks, active banks, real time banks, etc.) may be considered in alignment to the existing installation, the electrical processes/equipment involved, and the facility management style – this is however believed to be specialist application decisions and not expanded on in these brochures.

8 Power factor control maintenance

Capacitors have no moving parts to wear out and require very little maintenance. Fuses should be checked on a regular basis, and, if high voltages, harmonics, switching surges, or vibration exists, fuses should be checked more frequently.

Note:

It is not in the scope of this brochure series to elaborate on the effects of harmonics and its relation to power factor and power factor correction. Depending on your electricity supplier and geographic area, a power factor less than 90% will be penalised, and although there are no penalties paid for the level of harmonics, their presence in the system can be far more costly than the power factor penalties. System harmonics should be considered when applying power factor correction capacitors. The application of capacitors in the presence of harmonics must be done with care.

Active harmonic filters with power correction can:

- √ Reduce energy costs from 5% to 30%;
- √ Increase personnel performance and productivity;
- √ Avoid utility penalties up to an additional 20%; and,
- √ Create an economic payback in 1.5 to 4.0 years.

For more information on harmonics and power quality please see the Eskom quality of supply brochure here…

9 Conclusions

The question of "will correcting power factor really reduce my electric bill" is not an easy question to answer. However, improving power factor is a proven way of increasing the efficient use of electricity by utilities and end-users.

Economic benefits for end-users may include reduced energy bills, lower cable and transformer losses and improved voltage conditions, while utilities benefit from released system capacity.

Capacitors are an effective, proven, and efficient means of improving power factor.

Eskom advisory service

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Eskom's role is to aid the client with basic information in the decision-making process. Thereafter the Eskom Advisor will fulfil the role of energy advisor as part of the team that the business selects.

Optimise your energy use

Eskom's Energy Advisors, in regions across South Africa, offer advice to business customers on how to optimise their energy use by:

- Understanding their energy needs
- Understanding their electrical systems (including quality of supply) and processes
- Investigating the latest technology and process developments, including electric infrared heating and drying systems
- Analysing how to reduce energy investment costs
- Optimising energy use patterns in order to grow businesses and industries

Call **08600 37566**, get a reference number, leave your name and number and request that your Energy Advisor contacts you. Alternatively, e-mail your advisor at ***advisoryservice@eskom.co.za***.

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